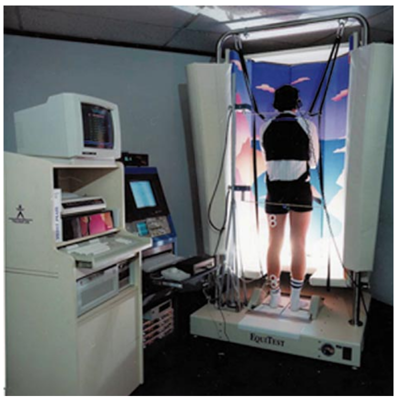
Which Way is Up?

Spatial Reorientation Following Space Flight

Recall the childhood experience, after spinning round and round, when you stop but still feel like you are spinning? Afterwards, you couldn't walk well and often fell into an uncoordinated jumble. The vestibular system, a set of organs in the inner ear, causes that befuddling sense of movement after you have stopped moving. The culprits are the semicircular canals in your inner ear: hollow tubes filled with fluid that contain sensory hair cells. As your head spins, the fluid begins to move at the same rate as your body; when you stop, the fluid continues to move and to stimulate the hair cells. Another part of the vestibular system is the otolith organs, which contain small calcium carbonate crystals that stimulate hair cells during acceleration. When sitting in a car with your eyes closed, notice the feeling of motion as the car first accelerates. The otoliths detect this acceleration.



The computerized dynamic posturography system, shown above in ground testing, disrupts astronauts' sense of balance and analyzes how they reorient.

Imagine how astronauts feel: during the first days of a mission, they are subjected to almost constant disorientation similar to that sense of continued spinning. The vestibular system, particularly the otoliths, depends on gravity to sense our surroundings.

During space flight, the vestibular organs no longer respond in a familiar way. Instead, inputs from the inner ear do not match those coming from the eyes. While on Earth, you can open your eyes to see if you truly are spinning, but astronauts do not have this luxury. Astronauts can see the floor, but have no sense of down; when they bend their heads forward, the otoliths are not stimulated properly. This state, called sensory conflict, must be resolved by the brain to maintain orientation. When they first return to Earth, astronauts are again disoriented because of sensory conflict. They undergo a period of spatial reorientation, as their brains reconcile what their eyes see and what their vestibular system senses. Recovery can take anywhere from hours to days depending on the length of the mission.

Earth Benefits and Applications

These studies are designed to find ways to keep astronauts safe and also to help patients with related conditions on Earth:

- Nystagmus
- Vertigo
- Meniere's disease and other balance disorders, affecting over 90 million Americans
- Vestibular system injuries
- Senior citizens, who are at high risk of injury from falling due to the natural aging process.

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Background Information

Science

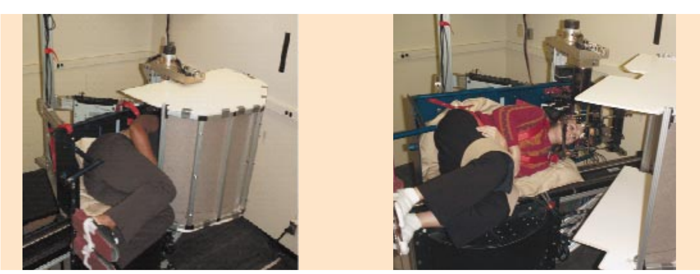
Spatial orientation is the way that the brain uses information from many sensory systems, including the vestibular, visual and body sense systems, to formulate a complete mental map of the body within its surroundings. Using this mental map, the brain can send commands for appropriate movements to the muscles.

Scientists hypothesize that during space flight, astronauts develop a head-centered point of reference to orient themselves and to compensate for missing input from the inner ear. They will test this by challenging the spatial orientation system of the astronauts with a short-arm centrifuge.

With the centrifuge, they will subject the astronaut to an environment of altered gravity and inertia. Changes in spatial orientation will be studied by testing the response to the centrifuge before flight to establish the astronaut's normal reaction and balance. The astronaut will be tested again after flight near the end of the Earth readaptation process to measure the fragility of the spatial orientation adaptation. Scientists will compare the data from tests before and after flight to see how the processing of vestibular input changes during flight.

Hardware

These studies will use a human centrifuge, specially designed to stimulate the inner ear and provide sensory conflict. An infrared video camera allows three-dimensional measurement of eye movements. Readaptation to Earth will be monitored using computerized dynamic posturography, a complex system that tests astronauts' ability to maintain an upright posture in response to varying sensory stimuli; in the simplest terms, the posturography system tilts and otherwise disrupts the balance of the subject. Scientists use a motion analysis system to analyze head and body movements, showing how well the astronaut is reorienting and moving. The system can record details of the astronaut's movement using infrared markers attached to various locations on the bod, and a three-dimensional video analysis system to track the marker movements.



The short-arm centrifuge will subject the astronaut to conflicting sensory input and study the astronaut's perception of motion.

Operations

Ten astronaut subjects, preferably those who are flying for the first time, run through a battery of tests before and after flight. Astronauts use equipment that challenges their balance. Comparing postflight to preflight results, scientists will specifically look at a shift in the way that vestibular input is processed, from gravity-based to internal, head-centered.

Additionally, scientists will put the astronauts on a short-arm centrifuge. Subjecting astronauts to conflicting sensory input while they are readapting is believed to cause a return to the head-centered frame of reference. Preflight testing consists of standard activities at 60, 30, and 10 days before launch. Normal balance data will be collected, with more data gathered before and immediately after centrifugation. During centrifugation, researchers will record eye movements and the astronaut's perception of motion. Centrifugation and testing begin two hours after landing and continue periodically for eight days. The test procedures are unchanged, except for videotaped interviews held during the first postflight session to explore the astronaut's own impressions.

Earlier Results

Analysis of data collected from the STS–104, STS–105, and STS–109 missions is now underway.